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A 180 degree curved lightbar is used at the Naval Air Development Center for the dynamic tracking of a subject's peripheral vision during experiments in acceleration physiology. A training regimen was designed to instruct new subjects, and to refine the tracking performance of experienced subjects. The NAVAIRDEVCEN lightbar control system was modified to allow the input of computer simulated peripheral light loss. A training officer, instructing subjects on the mechanics of the tracking task, used a joystick to move an imaginary peripheral threshold on the lightbar. A measure of the subject's tracking error was relayed to the trainer, and the subject was coached to accurately track the threshold. Eight male subjects took part in a two week lightbar training experiment immediately before a scheduled centrifuge project began. At the conclusion of the training period, all of the subjects could track the threshold with a high degree of precision and accuracy within the limits established prior to the start of the experiment. The subjects who had previously ridden the centrifuge showed a greater consistency in

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19. ABSTRACT. (continued)

their tracking performance in the project subsequent to the training. The proper training of acceleration research subjects for the tracking of peripheral vision would give experimenters a greater confidence in the measurement of this parameter.

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A TRAINING METHOD FOR THE DYNAMIC TRACKING OF PERIPHERAL VISION LIMITS

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APPROVED BY: W J Gallagher DATE: 31 December 1985

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INTRODUCTION

Experiments to evaluate human tolerance to high +Gz levels are routinely carried out on the Naval Air Development Center's human centrifuge Dynamic Flight Simulator (DFS). As subjects are exposed to increasing levels of acceleration in the head-to-toe dierection, the blood flow to the head is decreased and they experience visual symptoms that progress from overall dimming, through peripheral light loss, to complete blackout before loss of consciousness sets in. The endpoint of the NAVAIRDEVCEN's acceleration experiments is usually taken as the point where the subject's field of vision has collapsed to a pre-selected value, most often a 60 degree visual cone. This report describes the operation of the NAVAIRDEVCEN peripheral vision tracking light bar and a training regimen designed to instruct new subjects and refine the tracking performance of experienced centrifuge riders.

THE LIGHT BAR

The NAVAIRDEVCEN light bar is the instrument which is used to measure a subjects peripheral vision during exposure to +Gz acceleration in the human centrifuge. The mechanical portion of the light bar is a fixed aluminum semi-circular channel, 76 centimeters (30 inches) in radius. It is mounted at approximately eye level with the ends of the light bar even with the subject's eyes to give peripheral coverage of 180 degrees [figure 1]. Mounted on the metal channel are 118 discrete light emitting diodes (LEDs, Dialight #521-9178), 59 on either side of the centerline. The LEDs are spaced at increments of 1.5 degrees starting at 180. The LEDs are capable of being lit up to appear red, green, or both, giving the illusion of yellow. The LEDs are wired in a matrix configuration so that only 24 wires are needed to interface the light bar to the drive electronics which will light one pair of LEDs, one at the same visual angle on each side of the centerline, with one digital command word from the controlling computer.

The light bar is operated under the control of a Cromemco Z-2 microcomputer. This computer is a small S-100, CP/M system using a Z-80 microprocessor. The computer has the capability for I/O through 7 analog input channels, 7 analog output channels, one digital input channel (8 bits), and one digital output channel (8 bits). The computer sends a single byte to the light bar drive electronics to light a pair of LEDs at the specified position. The subject has control over the position of the LEDs through a force control joystick (Measurement Systems Inc., Model 446). The joystick produces a voltage proportional to the amount of pressure the subject exerts on the fixed control stick. This voltage is sampled by the computer. The control algorithm sets up a driving function that the subject must counteract to maintain the lights at a fixed position. This is a safety feature so that if the subject should release his grip on the stick, the lights would run in towards the center position, thus terminating the run. In effect, the joystick input is integrated and added to the driving funtion to yield the light position.

$$P(t) = \int (d + g*s(t))\, dt$$

Where: P(t) -- Light position
d -- driving function constant
s(t) -- joystick input
g -- sensitivity gain constant

The use of the computer to control the lightbar allows for great flexibilty in establishing the performance characteristics. The light bar program, written entirely in FORTRAN IV, allows the light bar to be configured according to the following parameters:

1. Sensitivity of the subject's joystick
2. Configuration of the light bar to light either one or two LEDs per side and specify the distance between lit LEDs if the two per side option is chosen.
3. Speed of the driving function in degrees/second
4. Termination threshold in terms of degrees of visual cone remaining
5. Time delay to run termination after the subject has tracked past the threshold
6. Dither option which causes the LED at the tracking position and the LED immediately aft of this position to blink alternately at a rate of about 3 cycles/second.

Figure 2 shows various light bar display mode options.

The light bar program also generates several analog output signals for monitoring and status indication:

1. A voltage proportional to the subject's tracking position. This signal is updated every 8 milliseconds.
2. A relay drive signal that sends a stop signal to the centrifuge operator at the proper times.
3. An event marker that indicates status during the run. The major indications of this marker are:

a. 0.0 vdc -- Idle
b. 0.5 vdc -- Subject has Started Tracking
c. 1.0 vdc -- Start of G Profile
d. 1.5 vdc -- Peak G reached
e. 2.0 vdc -- Visual cone less than 60
f. 2.5 vdc -- Threshold reached
g. -2.5 vdc -- Stop run signal to centrifuge
h. -1.0 vdc -- End of G (Normal Stop)
i. -0.5 vdc -- Peripheral vision fully recovered

THE TRACKING TASK

The subject is instructed to track his peripheral vision as follows. If the subject does nothing, the lights will advance towards

the center of the light bar. The object is to pull back on the control stick when the lights are visible and continue to pull back until the lights go behind the limits of the visual field. The stick may then be released, or pushed forward, to once again bring the lights into view. The process is then repeated. This simple task becomes more complicated, however, when subjective judgements come into play, such as:

1. How far should the lights run in before pulling back on the stick?
2. How much time should elapse after the lights disappear before letting them run forward again?
3. How fast (often) should the operation be performed?

Although there are as yet no definitive answers to these questions, there are several considerations which influence tracking `style'. The most important factor to be considered is safety. If the application of +Gz is in the form of a moderate rise time to plateau, after a total loss of vision (blackout) and cessation of blood flow to the brain, there remains only about a three to four second oxygen reserve in the tissues of the brain. By accurately monitoring peripheral vision, during experiments with moderate rise times, the acceleration may be removed before a loss of consciousness occurs.

One excursion of the lights will ideally indicate points in front of and behind the subject's current peripheral visual limit. However, the actual position of this limit cannot be determined from a single cycle of the lights. One cylce of the lights every three seconds would therefore not be a good indication of visual status within the allowable safety considerations. Three cycles, one per second, would give a much better indication of the limits of the subject's peripheral field. At frequencies much higher than this, precise control of the lights by the subject becomes difficult. The magnitude of the swing of the lights now comes under consideration. The smaller the total excursion of the lights, the better the estimate of the midpoint which is the edge of the periphery. If there is a large change in the state of the visual field, however, the subject would quickly lose the lights if very small strokes were used.

The problem arises with properly instructing a subject to perform this task in that formerly there was no way of judging whether or not the tracking task was being done correctly.

THE TRAINING SYSTEM

A system was developed at the NAVAIRDEVCEN to train new subjects to accurately track their peripheral vision. The computer program that was used to operate the lightbar was modified so that a training officer could simulate peripheral light loss on the light bar in a realistic tracking environment [figure 3].

The light bar was set up in a sound chamber along with an aircraft seat, control stick, video camera, two-way audio communications, EKG amplifier, and an ultrasonic doppler flowmeter [figure 4]. The chamber was dimly illuminated to simulate the lighting conditions inside the gondola of the human centrifuge. Outside of this chamber,

a training station was set up with a video monitor, strip-chart recorders, two-way audio communications, and a joystick operated by the training officer.

The training officer used the joystick to move an imaginary peripheral threshold on the light bar. The algorithm to establish this position is similar to the normal tracking algorithm except that there was no driving function associated with the imaginary threshold. The output of the trainer's joystick is integrated to get threshold position, so that if the stick is released, the threshold will remain in its current position. The computer program was altered so that if the subject is tracking in front of the threshold, the LEDs at the tracking position will be lit as in normal operation. If, however, the subject tracks the lights behind the threshold, the computer will extinguish the LEDs and no lights will be visible. Using this configuration, the subject can track the border of the set imaginary peripheral threshold and thus simulate the tracking task during peripheral light loss.

The training officer monitors the subject's performance on strip-chart recorders. Along with the subjects tracking position, the modified program also generates analog signals for the threshold position and an error signal which is the difference between the subjects tracking position and the threshold position. The training officer then looks for smooth transitions above and below the zero error level and an appropriate frequency and amplitude. The trainer offers corrective instructions and coaching to guide the subject to learn to track the threshold and its changes with a fine degree of control.

The lightbar training session also provided an opportunity to train new medical personnel in subject preparation. While learning to track the light bar, subjects were fully clothed in flight suit, flight boots, anit-G suit, torso harness, and flight helmet. They were instrumented with EKG electrodes, a finger plethysmograph, and an ultrasonic doppler flowmeter transducer placed over the superficial temporal artery. This was exactly the same equipment as that worn in the gondola of the human centrifuge during acceleration studies. The training profiles used by the instructors to set the thresholds were chosen to simulate possible visual experiences under acceleration. After the subject began to get comfortable with tracking a fixed threshold, the profiles listed in table 1 were presented by the instructor. The training program was designed to simulate the experimental environment with everything present but the acceleration. The profiles in table 1 emphasize the need not only to track decreasing peripheral vision, but also to accurately track any peripheral recovery. The recovery of peripheral vision during acceleration could be an indication of physiological compensation or a straining maneuver by the subject.

RESULTS

The purpose of the lightbar training experiment was to firm up the tracking practices among subjects and to elicit similar tracking signatures during subsequent acceleration studies. In begining this training exercise, the investigators did not know what the optimal tracking profile was. Taking into consideration the safety aspects of

a subject under acceleration, the training officer was instructed to direct the subjects to achieve a tracking pattern that was fairly rapid (0.5 - 1.0 cycles/second) and not extremely large in amplitude (less than +/- 10 degrees). These numbers were chosen arbitrarily since the tracking capabilities of the subjects were not known. The experiment was begun not only with the objective of training acceleration research subjects, but also to gain some direction for future training and tracking techniques.

Figure 5 is a reproduction of strip-chart recordings taken during the light bar training experiment. The top channel indicates the subjects tracking position in degrees. The middle channel indicates the threshold position set by the training officer. The third channel is the error or difference between the first two. An error signal below the zero degree reference line indicates that the lights are extinguished on the light bar. The top half of figure 5 shows the tracking performance, during the first training session, of a subject that had never previously used the light bar. There was a constant dialogue between the training officer and the subject during this period to coach the subject into a rythmic tracking pattern. While the subject reached the desired form of tracking after this session, the period of oscillation was about once every five seconds with an amplitude of +/- 15 degrees. Also note that the threshold remained at zero (full periphery) during the entire first session. The bottom half of figure 5 shows the same subject after the fourth training session. The subject is now tracking at a frequency a little lower than one cycle/second and at an amplitude of +/- 7.5 degrees. The subject is also able to follow changes in the threshold with ease.

An interesting realization occured when the investigators were observing tracking performance early in the experiment. Those subjects with very small tracking error were considered `better' than those with a larger but still acceptable error. This observation was based on performance during steady-state and very slowly varying threshold levels (approx. 1 deg/sec). As the training progressed, the thresholds were changed rapidly (30 deg/sec) to simulate sharp losses of peripheral vision. The subjects that did `very well' on the steady-state tracking were unable to follow the sharp changes of the new threshold profile and spent an average of 2-4 seconds to hunt down the new threshold position [top half of figure 6]. Therefore, very small tracking error during steady-state threshold levels is not necessarily a desirable trait. The subject in figure six was coached to give a little wider variation in the tracking oscillations and can now track sharp changes in the threshold at the same error level as steady-state.

Figure 7 illustrates that the static training in the sound chamber was transferred to the dynamic environment of the human centrifuge. The top half of this figure shows a subject involved in an acceleration study before the light bar training experiment. The tracking signal shows very wide variations of up to +/- 20 degrees and a lack of any consistent pattern. It would be difficult to pinpoint a mean peripheral limit from this tracking performance. The bottom half of figure 7 shows the same subject during an acceleration study that immediately followed the training experiment. The variations are greatly reduced to +/- 5 degrees and a definite pattern can be seen with the mean peripheral limit readily apparent.

Figure 8 compares the tracking performance of two subjects during G-tolerance runs on the centrifuge. The lower half of figure 8 shows the tracking performance in which the subject lost almost all of the visual field. Note that the tracking performance is consistent throughout the entire run which leads the investigators to feel confident that this is a true repesentation of the subject's peripheral limits. This subject had just completed light bar training prior to volunteering for the acceleration study. The top half of figure 8 shows an experienced subject in a much earlier study. There were few controls placed on subject tracking performance prior to this training experiment.

CONCLUSION

In acceleration research, the limits of a subject's visual field are an important indication of his physiologic response to acceleration. In an attempt to accurately measure this parameter, the NAVAIRDEVCEN light bar was developed. Subjects were instructed in the operation of the light bar but were not previously trained in the tracking task. A training regimen was designed to instruct new subjects and to refine the tracking skills of experienced subjects.

The training officer was an invaluable asset in the initial instruction of the tracking task. The subjects were coached into the desired tracking pattern and then this pattern was refined to the point where the subject was tracking the changes in the threshold level with a high degree of accuracy and precision. In trying to compare subject performance, however, there is a definite need for computer generated threshold profiles. The subject's tracking performance could then be automatically scored based on amplitude of oscillations, frequency, and time-to-recovery during sharp threshold transitions. All of the subjects in the study had no trouble in getting the tracking amplitude in the range of +/- 5 to 10 degrees. Amplitudes less than 5 degrees on steady-state threshold levels were discouraged because of a demonstrated lack of ability to track sharp threshold changes. The period of oscillations ranged from 1.1 to 1.8 seconds/cycle. This parameter is highly subjective and is dependent on how comfortable the subject feels when tracking at a particular frequency. The mean period was 1.6 seconds/cycle. All of these frequencies were deemed acceptable in terms of safety and the investigators saw no need to coach in a `unnatural' tracking frequency to obtain uniform results across subjects.

Formal light bar training will be included in the protocol for future acceleration studies. These sessions will incorporate automatic performance scoring for subject comparisons and additional training in the centrifuge under low G accelerations (2.0 Gz). With the formal training and the confidence in the tracking ability of the acceleration subjects, the investigators can put greater stock in the visual tracking parameter.

TABLE 1 - Threshold Profiles

Run #	Description
1	1 min at zero (no PLL)
2	GR-30, GF-0
3	GR-60, RF-0
4	GR-50, GF-30, GR-90, RF-40, GF-0
5	RR-30, HOLD, RF-0
6	RR-30, HOLD, RR-50, HOLD, GF-0
7	RR-50, HOLD, RF-0
8	GR-40, GF-20, GR-70, GF-0
9	GR-40, RF-10, RR-30, GR-50, RF-30, GF-0
10	RR-50, HOLD, RF-20, HOLD, RR-60, HOLD, RF-0

Notes:
1. All runs preceded and ended by 15 sec. at 0
2. Gradual means 5-15 seconds
3. Rapid means 1-3 seconds
4. GR - Gradual Rise
   GF - Gradual Fall
   RR - Rapid Rise
   RF - Rapid Fall

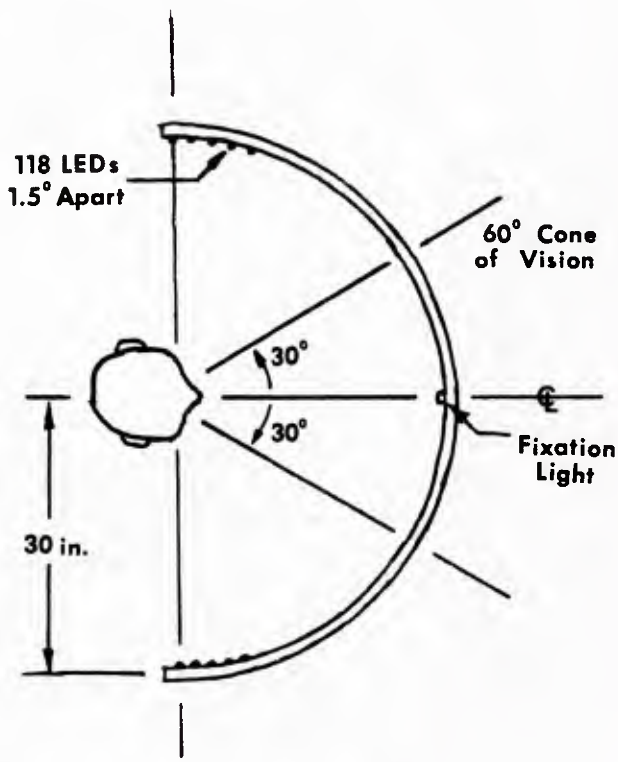


Figure 1 – NADC Light Bar

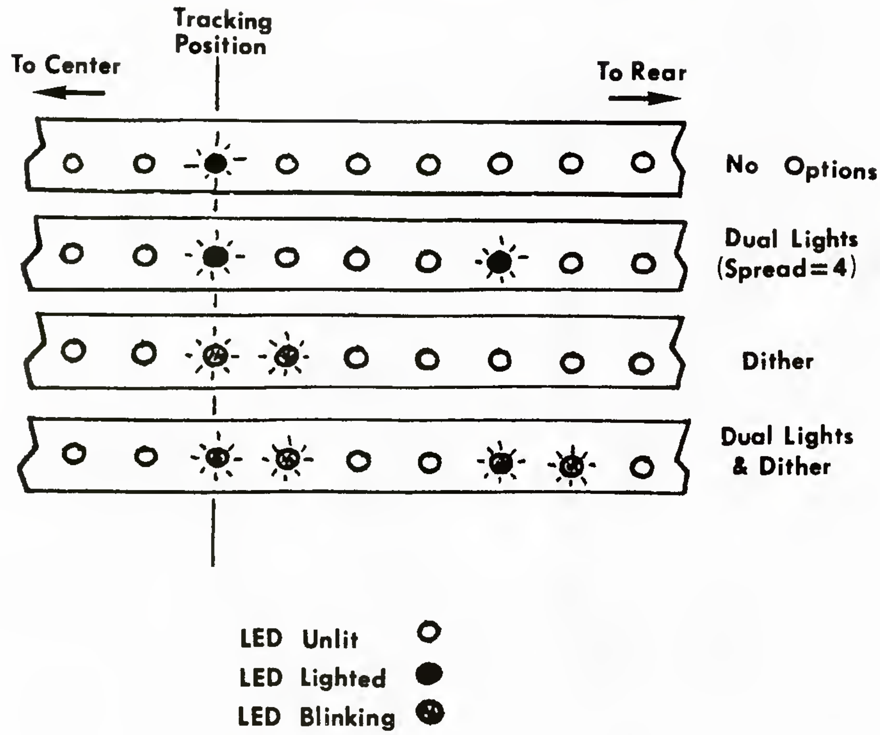


Figure 2 — Light Bar Display Modes

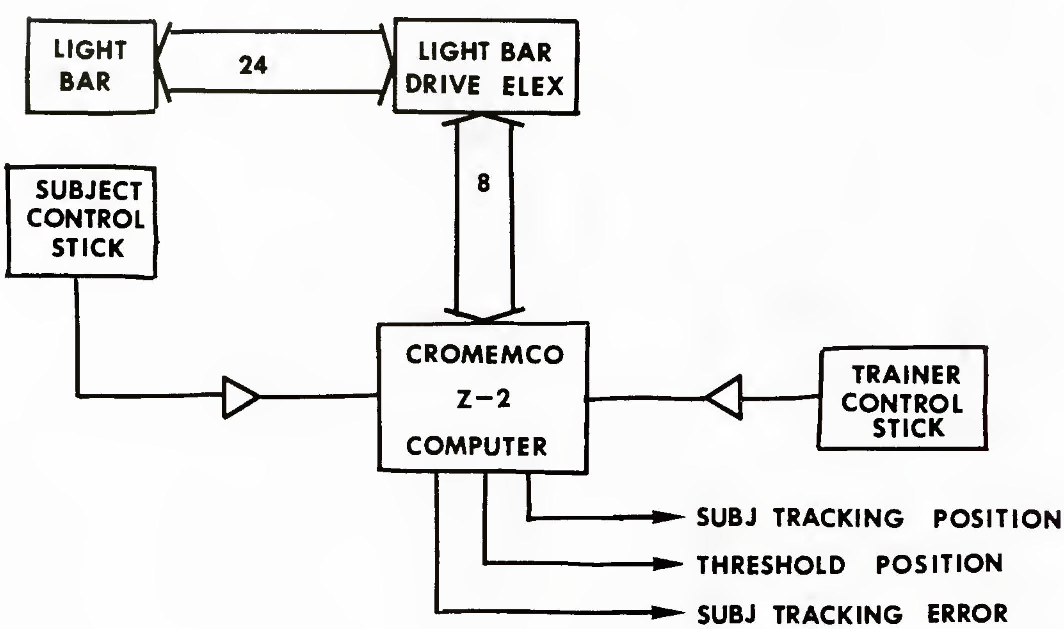
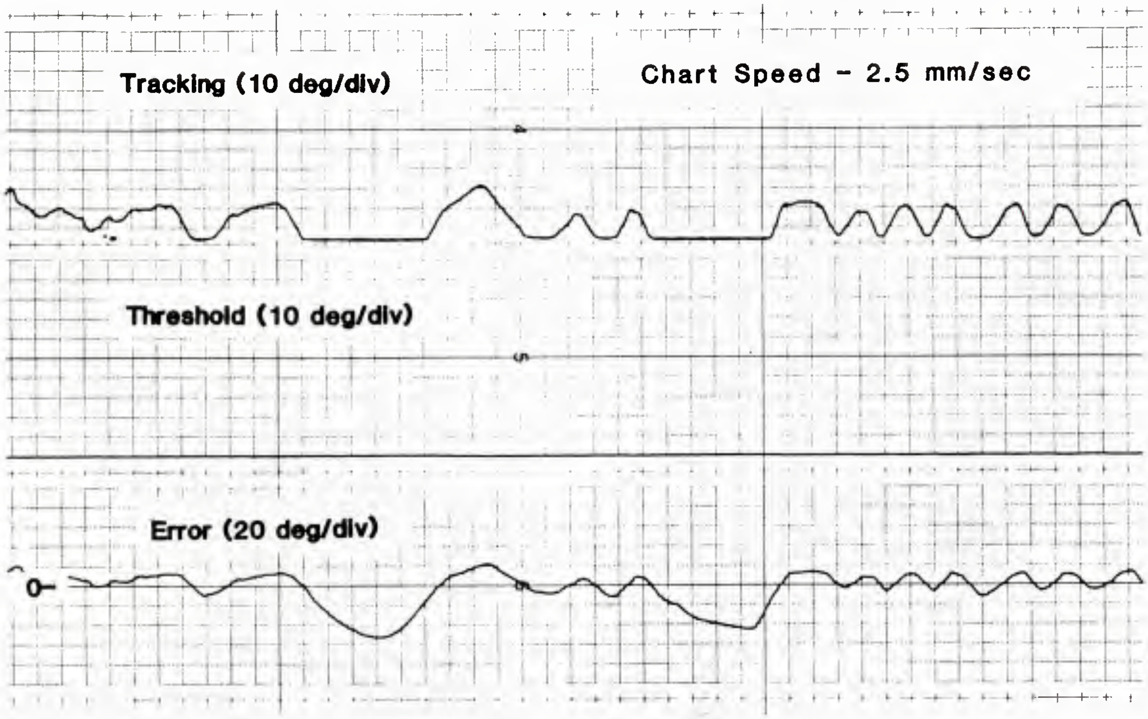
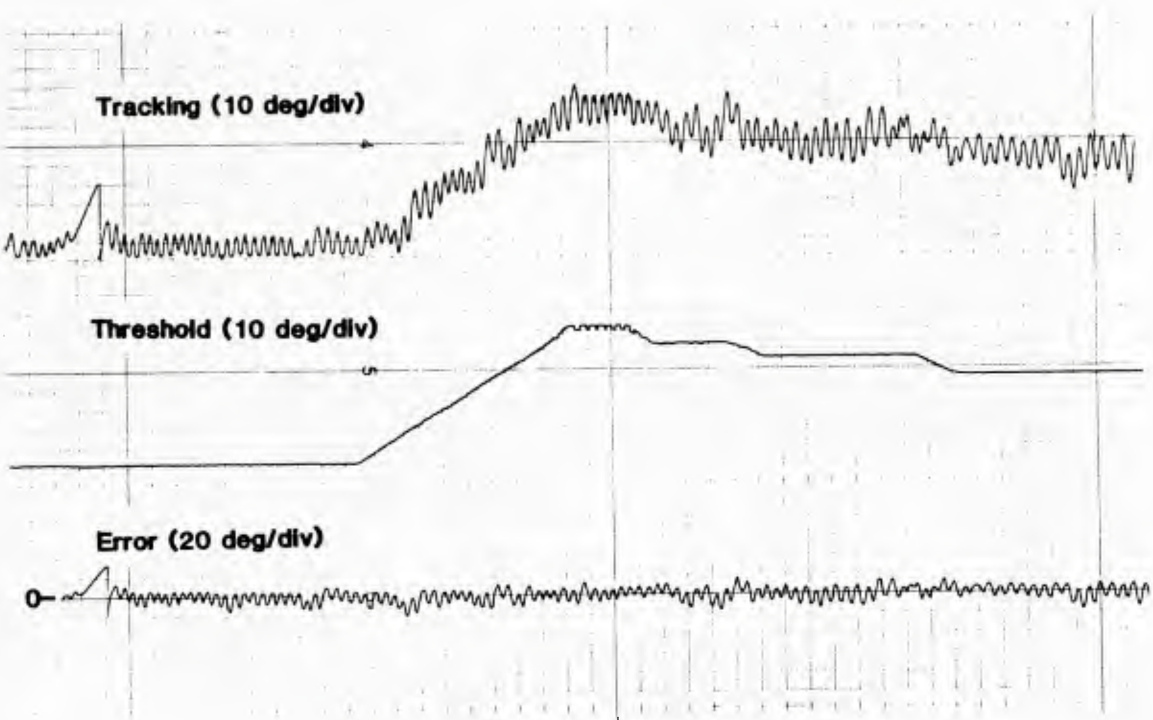


Figure 3 — Training Configuration

Figure 4 — Sound Chamber

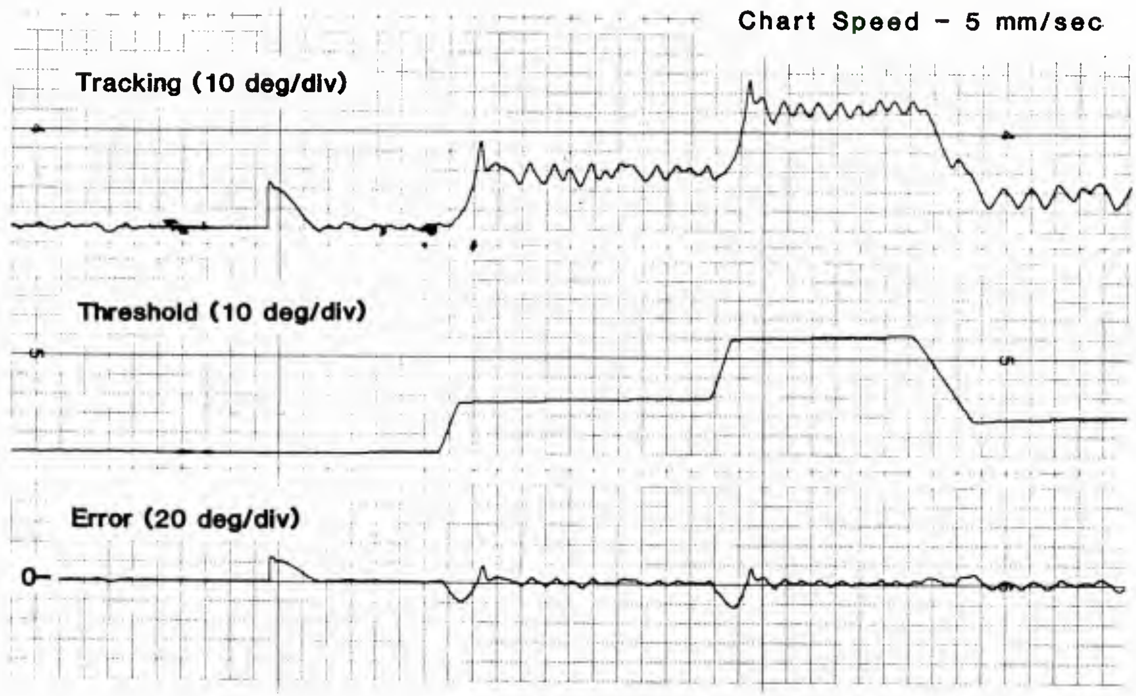


New Subject During First Training Session

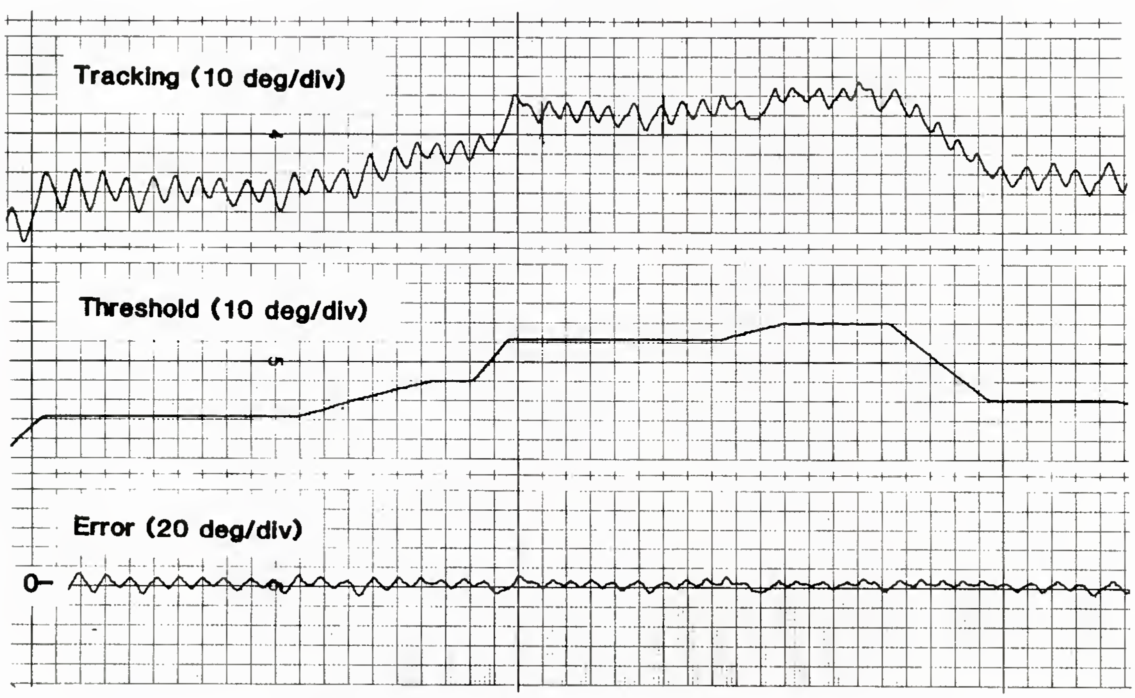


Same Subject During Fourth Training Session

figure 5 - Subject Progress During Training

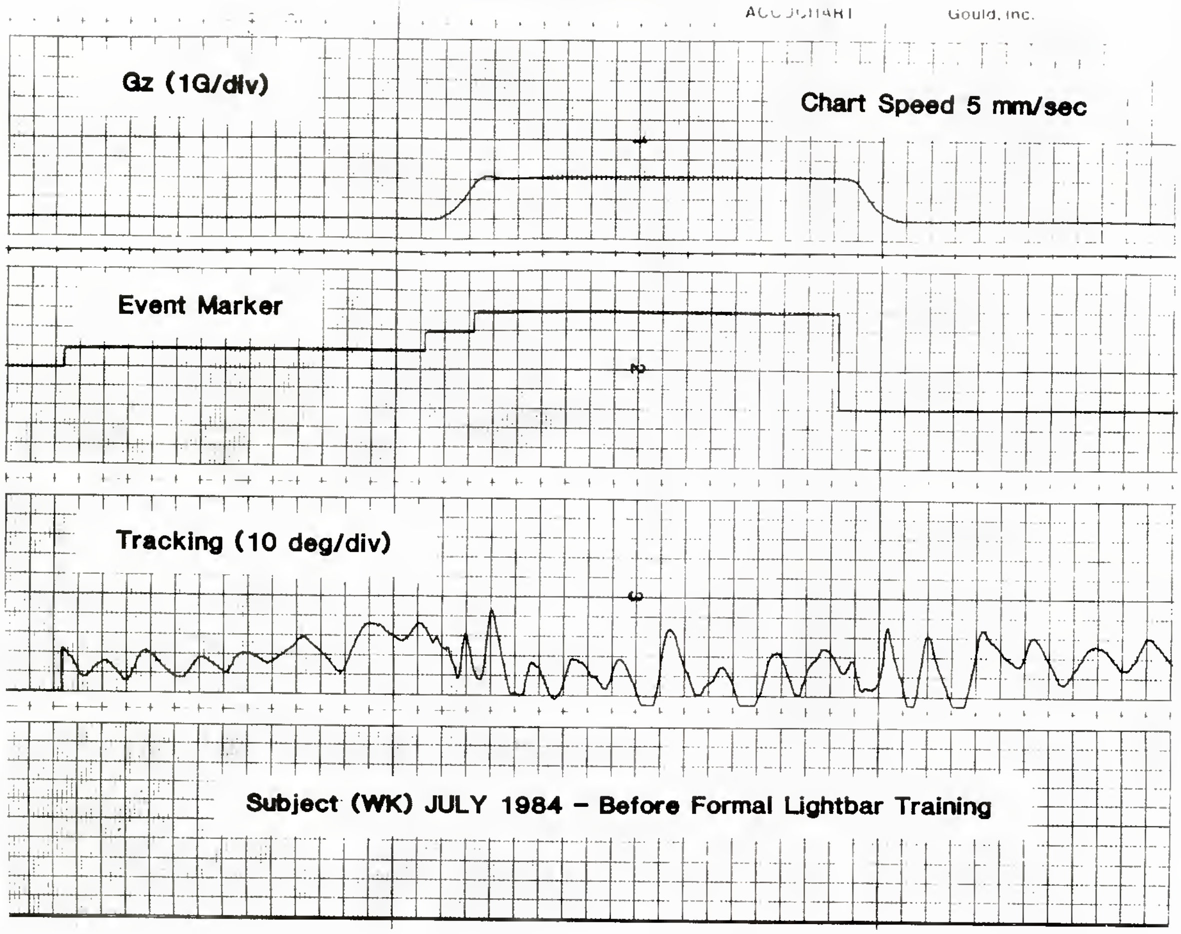


Tracking Amplitude Small - Sharp Changes Missed



Same Subject After Corrective Instruction

figure 6 - Size of Tracking Error Considerations



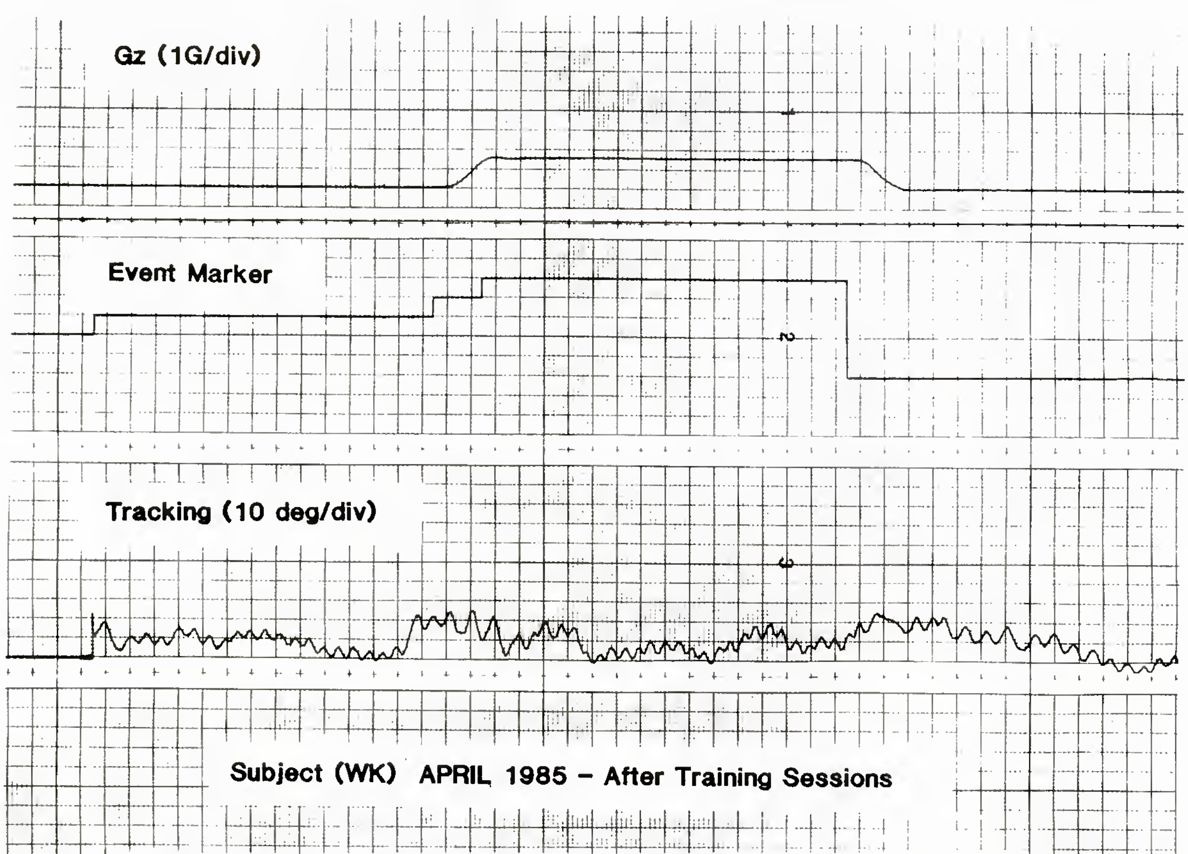
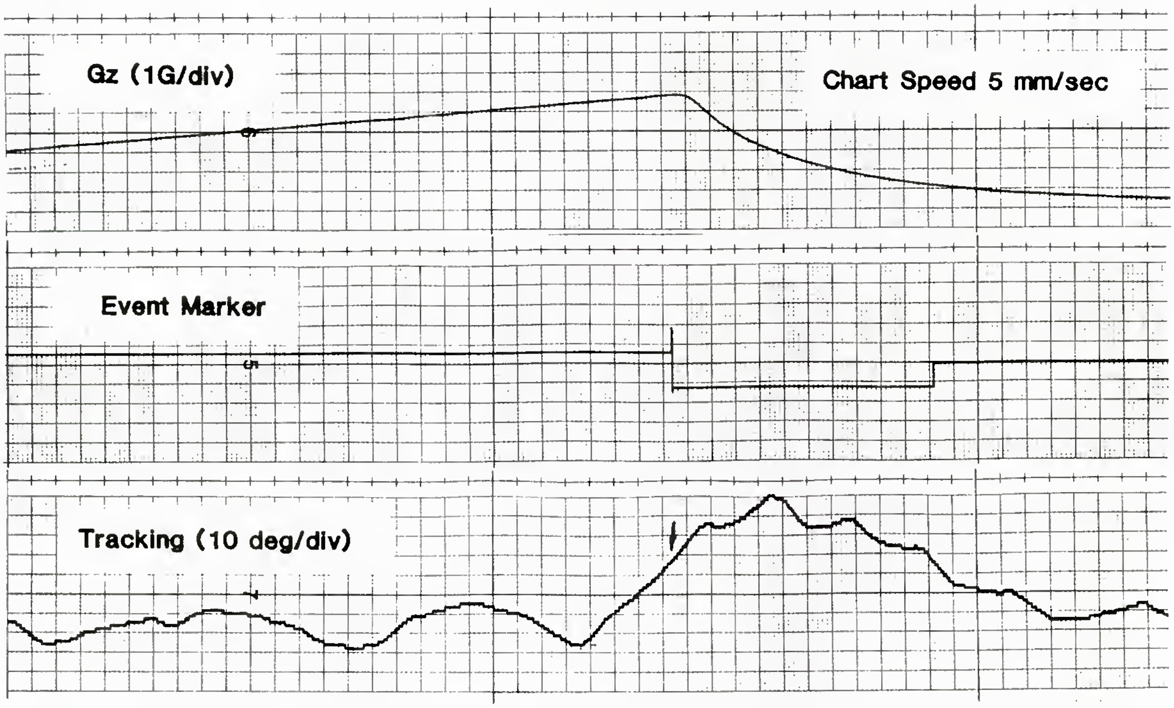
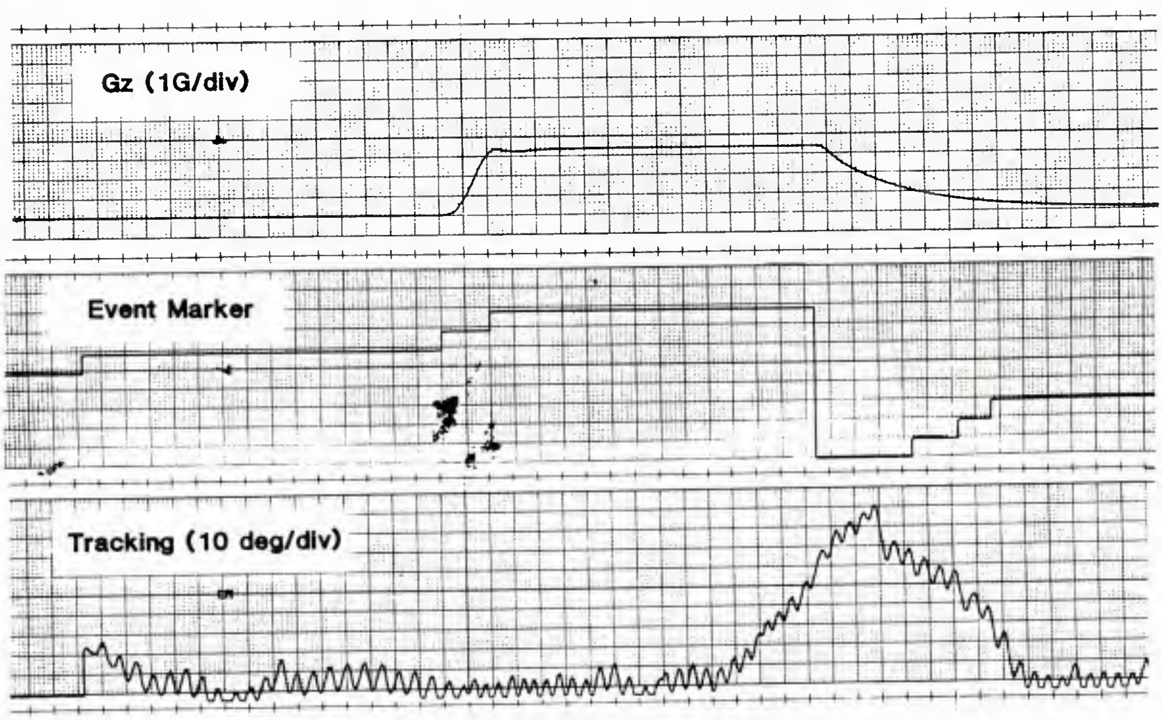


figure 7 – Transfer of Training to Dynamic Environment



Experienced Subject - 1983 Study



New Subject Trained in Tracking - 1985 Study

figure 8 - Comparison of G Tolerance Runs

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